Influence of Cane Number and Diameter, Irrigation, and Carbohydrate Reserves on the Fruit Number of Red Raspberries[1]

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Abstract. Fruitfulness of individual red raspberry (*Rubus idaeus* L.) canes was increased by reduction of cane number per hill and by increase in cane diameter. Yield per hectare, however, was greatly increased by more canes per hill. Floral primordia bud number was more advanced in the fall on small-diameter canes, but the difference between small- and large-diameter canes disappeared by spring. Berry number and percentage fruit set were greater for large-diameter canes and were related to amount of available carbohydrate per node. Excessive moisture stress in late summer tended to delay carbohydrate build up.

Precocious primordial flower bud development does not always result in higher yields the following summer (3). Buds of small-diam canes develop further in the fall but large-diam canes produce more berries per lateral (4). Several workers (6, 7, 15) have noted that as cane populations increase, berry numbers per lateral decrease. Brierley (2) attempted to show, by correlating primocane and floricane growth, that competition for nutrients exists between them, but his results were inconclusive. Lawson and Waister (5,6) concluded that sucker growth competes with fruit production and that this interaction must be taken into account when interpreting results of cultural treatments.

The amount of carbohydrate (CHO) reserves in dormant canes has been measured (2, 13, 14), but little attempt has been made to relate it to the fruitfulness of canes. We examined factors that influence the number of berries produced by red raspberry canes.

Materials and Methods

Single, 17.5 m rows of 'Washington' red raspberry were selected for uniformity and thinned to 6, 9, or 12 canes per hill in a randomized block design with 9 replications. One cane was selected at random from each of the 15 hills per row. Nodes were numbered from the base, and the number of laterals, length of laterals, number of potential fruiting points, and number of fruits produced by each node were recorded during harvest. Data were kept separate for each .3 m increment up to a topped height of 1.5 m. Total yield of each row was obtained.

A similar experiment was carried out with 'Puyallup'. During the dormant season, after the old fruiting wood and weak canes were removed, 40 hills were selected that had a minimum of 12 good canes. Twenty hills were selected from a block which was irrigated up to mid-harvest and 20 from a block that received an additional irrigation after harvest. Cane number in half of these hills was reduced to 6 canes and in the other half to 12 canes per hill in a completely randomized design. All were topped at 1.4 m.

Three large-diam and 3 small-diam canes were tagged in each hill and measured for diam and height. As soon as the fruiting laterals on these canes had developed enough that flower buds could be seen (May 19), all flower buds on the top 6 laterals were counted. Again just before harvest (July 2), all buds over 3 mm in diam, flowers, and fruits were counted. The total was considered to be the actual number of berries for determination of percentage set. This procedure does not account for late blossoms that fail to set fruit. As a result, calculated percentages tend to be higher than in the 'Washington' experiment where only fruits were counted.

On March 10, 20 large-diam and 20 small-diam canes were selected at random from each irrigation block. The diam was measured, and the number of nodes from soil level to 1.4 m was counted. The section of cane from .9 to 1.2 m was weighed, dried, and reweighed, and the number of buds per section was recorded. Total sugars were determined for each cane section by the method of Shaffer-Somogyi (1); starch, according to Nielson et al. (9, 10). Milligrams of starch were converted to mg glucose equivalent by dividing by .9. Milligrams glucose equivalent was determined for total green wt and divided by the number of buds on the original sample to obtain mg glucose equivalent per bud.

The following year 'Willamette' canes were sampled at 2- to 4-week intervals from Oct. 15 to May 1. Ten large- and 10

Table 1. Fruiting characteristics of 'Washington' raspberry as related to cane section and number of canes per hill.

Characteristics	Per 0.3 m section of cane: Basal	2nd	3rd	4th	5th	Canes per hill: 6	9	12
Number of nodes	3.3A[z]	4.2B	4.4BC	4.7C	5.3D	23	21	22
Number of laterals	0.4A	3.0B	4.1C	3.9C	5.3D	18R	16S	16S
Avg length of laterals (cm)	38	38	41	38	36	36	38	38
Number of fruits per lateral	9A	12B	16C	17C	20D	19R	16S	14T
Number of fruits	4A	36B	67C	63C	103D	331R	262S	223S
% fruit set	71A	77B	80BC	82BC	84C	81	81	81
% fruit on each .3 m section of cane	1	13	25	23	38			
Yield (cwt/ha)						189	217	251

[z]Mean separation within rows, by Duncan's multiple range test at the 1% level.

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Table 2. Effect of cane number per hill and cane diameter on fruitfulness of 'Puyallup' raspberries.

	Percent berry set	Berries per lateral
6-cane hills	90*	19**
12-cane	86	17
Large diam	91**	19**
Small diam	84	15

*Significant at 5%, **significant at 1%.

small-diam canes were selected at random on each date. Their diam and heights were measured and the section from 1.1 m to 1.7 m of each was retained for analysis. The number of buds per section was counted after which each was excised, killed, and fixed in FAA and imbedded in paraffin. Fifty buds from each treatment were selected at random, sectioned with a rotary microtome, the number of visible flower buds in the median section counted, and the terminal bud rated for stage of development (3, 8). Chemical analysis procedure was the same as described above.

Results

The basal .3 m of 'Washington' canes had fewer nodes than upper portions and few fruiting laterals (Table 1). Average lateral length was nearly the same at all heights. The number of nodes, fruiting laterals, fruits per lateral, fruits per .3 m section, percent fruit set, and percent of fruit on each section increased with height. The upper 3/5 of the canes produced 86% of the total yield. The 6-cane hills had more fruiting laterals, more fruits per lateral, and more fruits per cane than hills with higher cane populations. However, the yield per ha was increased considerably by greater cane numbers. Canes per hill had no effect on percent fruit set.

'Puyallup' canes from 6-cane hills set a higher percentage of fruit (5% sign.), and had more fruits per lateral than those from 12-cane hills (Table 2). Large-diam canes had a greater percentage fruit set and more fruits per lateral than small-diam canes. There was no interaction of cane number or diam with fruit set or fruit number. Large-diam canes in 6-cane hills set fruit on 93% of their flowers while small-diam canes in 12-cane hills set fruit on only 80%. Fruits per lateral were 20 and 14 respectively.

The percentage stored sugar was greater in small-diam canes but the actual amount available per bud was greater in large canes (Table 3). There was no difference in percent starch but again the large-diam canes had considerably more CHO per bud. The higher total CHO available per bud was accompanied by higher percent fruit set and more berries per lateral.

Extension of the irrigation schedule later into the summer increased the available CHO per bud although not as much as did cane diam. Intermediate levels of stored food resulted in intermediate percentages of fruit set and fruits per lateral.

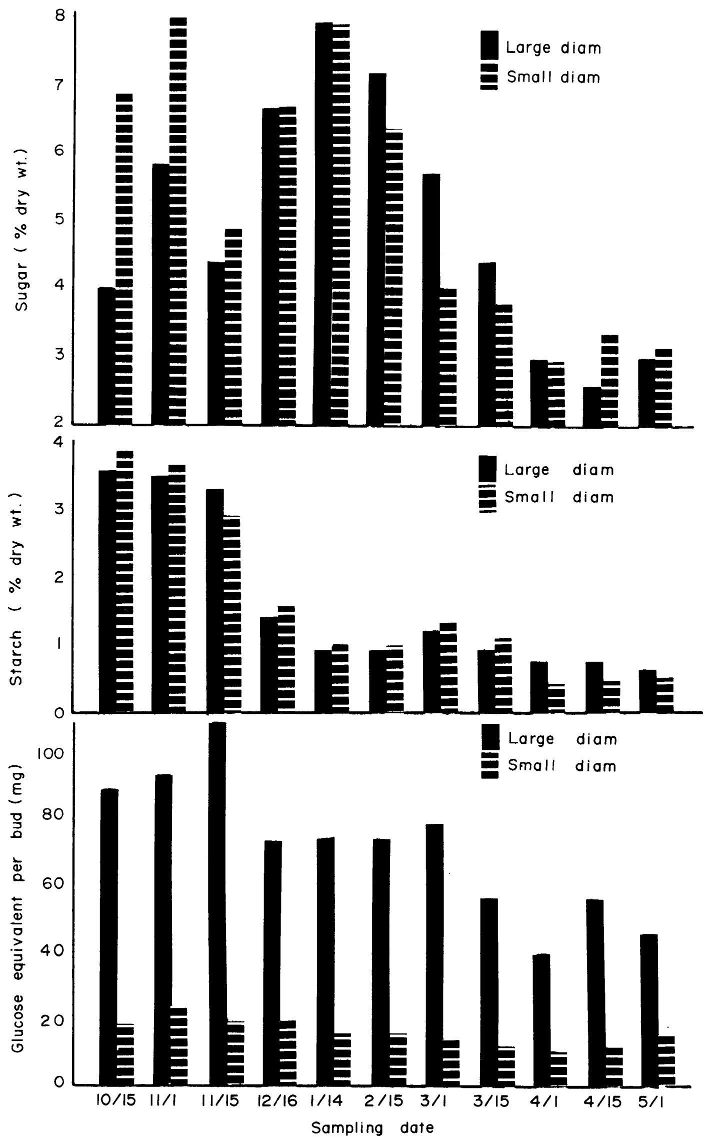

Fig. 1. Percentage sugar and starch (dry wt basis) and total mg glucose equivalent per node in 'Willamette' raspberry canes during the dormant season.

The percentage sugar in large-diam canes was lower than in small-diam canes during the late fall. However, after midwinter, the levels in small-diam canes dropped more rapidly than in large canes (Fig. 1). Starch levels were high in early winter but dropped to low levels after midwinter. The total glucose equivalent per bud remained much higher in the larger canes

Table 3. Effect of cane diameter and late season irrigation on carbohydrates, fruitfulness, and fruit set of 'Puyallup' raspberries.

	Cane diam		Irrigation	
	large	small	early	late
Cane diam (mm)	10.5	8.1	9.1	9.5
Topped height (m)	1.4	1.4	1.4	1.4
Number of nodes[z]	17.6	19.3	19.4	17.5
% sugar d.w.	2.68	3.09**	2.83	2.89
Sugar (mg glucose/bud)	67.1**	41.9	48.0	61.0*
% starch d.w.	2.73	2.70	2.75	2.68
Starch (mg glucose equiv./bud)	76.4**	41.6	51.0	67.0**
Total CHO (mg glucose equiv./bud)	143.5**	83.5	99.0	128.0**
% fruit set	91**	84	87	88
Berries per lateral	18.8**	14.9	16.3	17.4*

*Significant at 5%, **significant at 1%.

[z]Number of nodes from soil surface to topped height.

Table 4. Effect of cane diameter on primordial flower bud development of 'Willamette' raspberries during the dormant season.

Date	Number of buds		Stage of buds[z]	
	Large diam	Small diam	Large diam	Small diam
10/5	2.18	3.56**	2.76	3.30**
10/19	2.96	4.10**	2.90	3.68**
11/2	2.66	3.42*	2.94	3.34**
11/16	3.10	3.84*	2.90	3.22
12/1	3.60	4.62**	3.32	3.84**
1/7	3.93	3.93	3.23	3.52
2/1	3.25	3.71	2.94	3.31**
2/15	3.24	4.00**	2.96	3.56**
3/1	2.80	3.37	2.78	2.85
3/15	4.22	4.50	3.50	4.38**

*Significant at 5%, **significant at 1%.

[z]Means indicate stages of flower bud development described by Mathers (8); the larger the number, the more advanced the stage.

throughout the dormant period. All levels decreased as the season progressed.

Primordial bud development differed considerably between large and small canes in early October but by the time of bud break (Mar. 1) there was little difference in bud number (Table 4). The stage of flower bud development in small-diam canes remained more advanced.

Discussion

Early cessation of primocane growth results in smaller diam canes with earlier, more advanced flower primordia development (3). This difference in bud development mostly disappears by the time of bud break in the spring. From that time, the number of flower primordia that develop and set fruit is closely related to the supply of food materials, principally CHO, available to the developing fruit laterals. A part of this CHO is produced by the new leaves, but our research indicates that most of it must come from storage reserves. Additional confirmation of the influence of nutrition on the yield of raspberry canes is found in the work of Norton and Sheets (11). They found that by reducing competition for nutrients from new shoots by killing their tops with 2-sec-Butyl-4,6-dinitrophenol (dinoseb) during the blossom and fruit-development period, yields were increased in the year of treatment.

Moisture stress during the late summer apparently has an adverse effect on the amount of stored CHO available per bud. Hence, even though such a practice hastens the development of flower primordia, if carried to extremes, it may be detrimental to the productiveness of the planting.

Thus a few more steps have been taken in unravelling the major interrelationships that influence raspberry yields. Still to be determined are cultural practices necessary to produce desirable cane characteristics and their effects on berry size and cane number.

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